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(71) Applicant(s)
Jonathan Hugh Lambert Copus
55 Lower Ashley Road, Ashley, New Milton, Hants, BH25 5QF, United Kingdom

(72) Inventor(s)
Jonathan Hugh Lambert Copus

(74) Agent and/or Address for Service
Barker, Brettell & Boutland
Medina Chambers, Town Quay, SOUTHAMPTON, SO14 2AQ, United Kingdom

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(56) Documents Cited
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(54) **Voltage supply circuit with stabilised output control**

(57) The circuit comprises a transistor Q which switches a voltage across the primary winding of a step-up transformer T. The voltage induced in the secondary winding of the transformer is rectified and multiplied by a Cockroft-Walton voltage multiplier VM. A sensing circuit RSE senses the ripple in the output of the multiplier, its output being applied to an operational amplifier P whose output controls the gating circuit GC of the transistor. Such a negative feedback loop maintains the output current constant over a wide range of load resistance across the output of the circuit. When the breakdown voltage of a zener diode Z is exceeded, an operational amplifier L acts as a limiter to modify the operating parameters of the operational amplifier P to limit the max output voltage of the circuit in a gradual and controlled fashion. The circuit may be used in an electronic microbicide apparatus for killing micro-organisms.

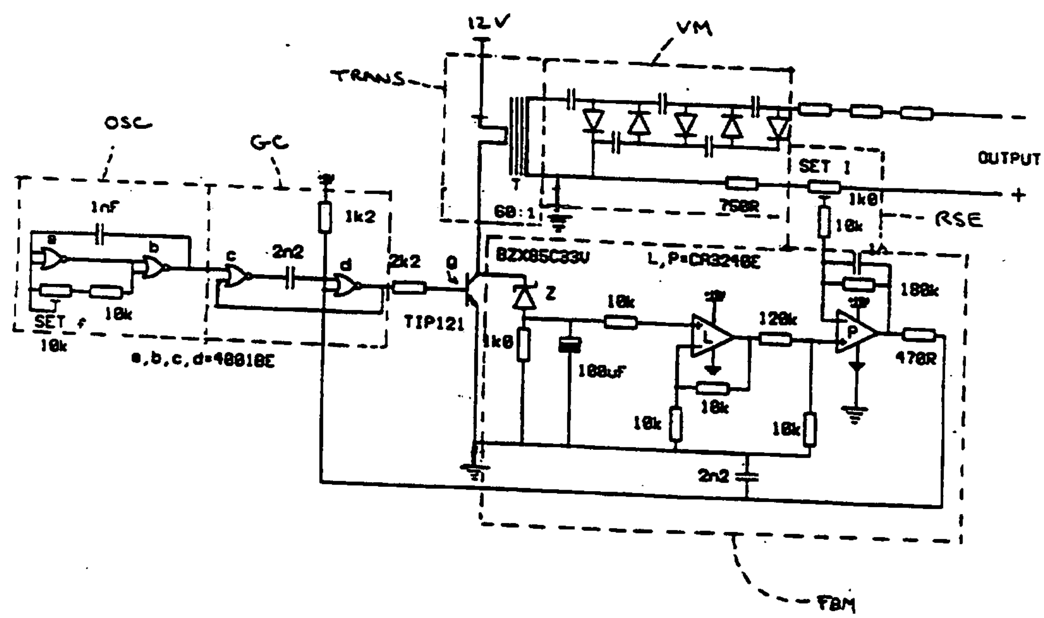

FIG 4

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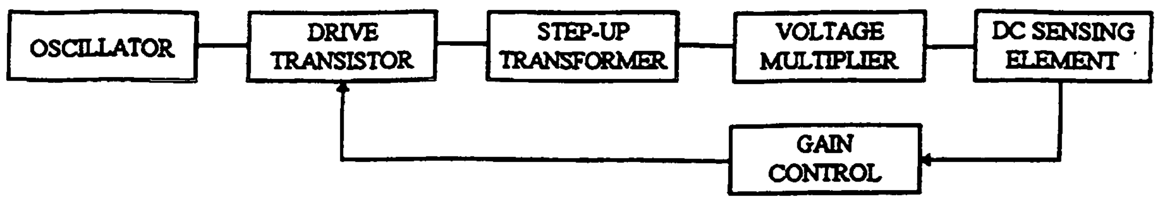

Figure 1 PRIOR ART

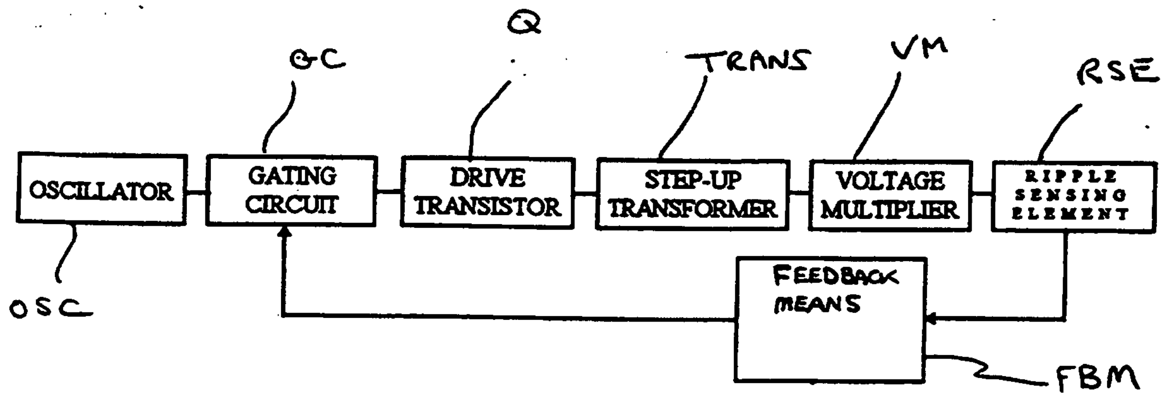

Figure 2

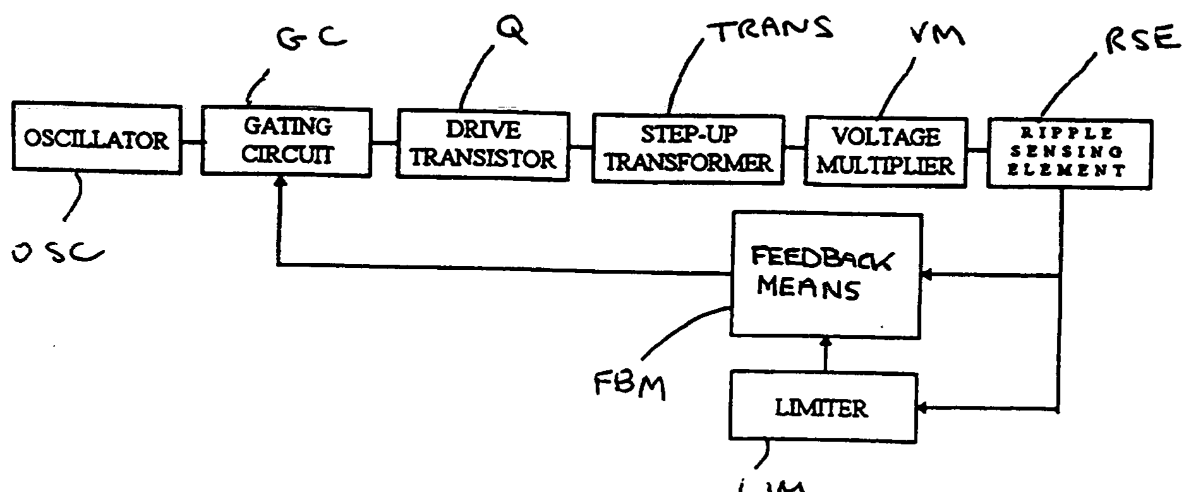

Figure 3

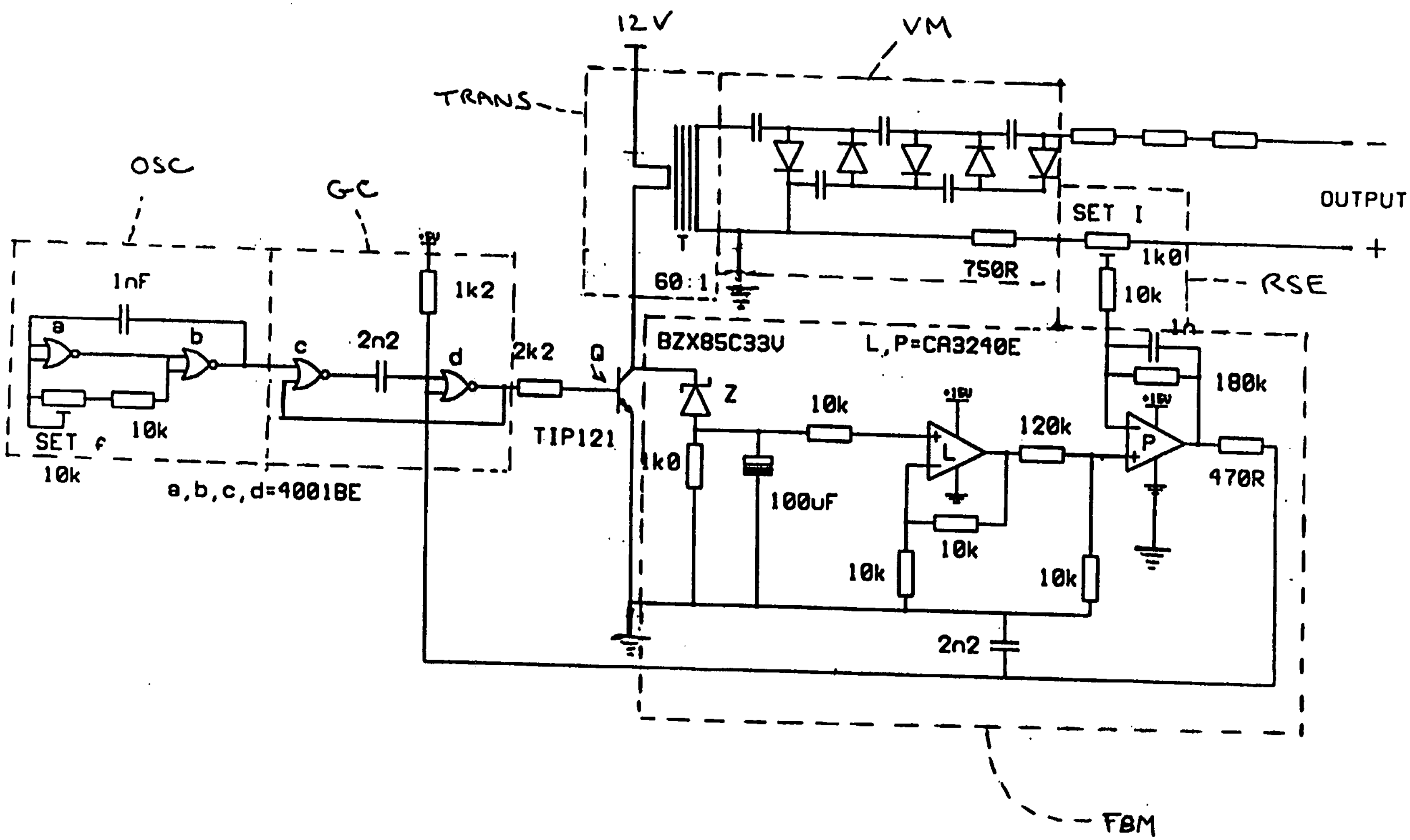
OSC
GC
TRANS
VM
12V
1nF
a
b
SET f
10k
10k
c
2n2
d
1k2
2k2
Q
TIP121
a,b,c,d=4001BE
T
60:1
750R
SET I
1k0
10k
RSE
OUTPUT
+
BZX85C33V
L,P=CA3240E
Z
10k
1k0
100uF
L
120k
10k
10k
10k
P
180k
470R
1n
2n2
FBM

FIG 4

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STABILISED OUTPUT CONTROL FOR NON-MECHANICAL ELECTRICAL GENERATORS

This invention relates to a circuit means for controlling the output of a non-mechanical electrical generator. The invention relates particularly, but not exclusively, to the control of the output current of high-voltage generators, and can provide control of the output current within narrow limits despite wide variations in load resistance. One application of the invention is particularly in the form of an electronic microbicide apparatus.

Many electronic devices incorporate high-voltage generators producing upwards of lkV. Typically in such generators an oscillator produces a waveform which is either amplified by a valve or transistor circuit to drive the primary of a step-up transformer or else is used to trigger the drive element into switching a separate supply across the transformer primary. The voltage produced across the secondary is then fed into a multi-stage Cockcroft-Walton voltage multiplier: this consists of a 'ladder' of capacitors charged by diodes, so configured that each successive half wave of the incoming alternating voltage is rectified and steered in such a way that it is added to the charge on each capacitor from the previous half cycle. The circuit thus acts as a pump, achieving a direct voltage which (ignoring losses) is equal to half the peak-to-peak value of the initiating alternating voltage multiplied by the number of stages in the multiplier. Impressed upon this direct voltage is a ripple equal to the alternating voltage across the secondary of the transformer.

Often there is a requirement for either the output voltage or the output current of a high-voltage generator to be regulated to take account of varying load conditions. These variations can be particularly wide-ranging.

For example, in processes involving some form of ionisation such as electrostatic paint-spraying or the generation of gaseous ions for medical, bactericidal or other purposes such as food preservation. The problem here is that the air-gap between the output electrode and the target site represents a finite but variable electrical resistance whose value is directly proportional to the length of the air-gap. With an unregulated supply, variation in the load resistance produces changes in the output voltage and current, the current increasing and the voltage decreasing as the load resistance lessens, and these changes can affect the efficiency of the process in undesirable ways.

One particular instance of the need for close regulation of output current arises in the application of a concentrated stream of negative air ions to kill micro-organisms on a conductive surface. In the case of one device for achieving this aim in a medical or dental context a high negative direct voltage is applied to a sharp point mounted in a probe handle of an electronic microbicide apparatus. An example of this type of device is disclosed in Patent Specification no. GB 2246955B. With the patient connected to the positive pole of the high-voltage generator the point is held near to the surface to be treated and a stream of gaseous ions flows from the point to the surface. To produce a constant dosage and therefore a consistent effect, the rate of ionisation should remain constant. This rate can be gauged by measuring the current flowing in the conductor connected to the point by using the formula:

$$N = I/e$$

where N = the number of ionisations occurring per second, I = the current flowing in the conductor connected to the point, and e = the electronic charge = 1.602×10^{-19} coulombs.

The distance between the point and the surface being treated is typically around 7 mm. However, difficulty of access to some parts of the body and muscular strain on the part of the operator can lead to variations in this distance over time. In the case of one device such variations were found to produce relatively large changes in the output current and hence the applied dose. The relationship between point-to-surface distance, output current and output voltage displayed by this particular device is illustrated by Table 1.

POINT/SURFACE DISTANCE (MM)	OUTPUT CURRENT (μA)	OUTPUT VOLTAGE (KV)
4.0	100	6.4
5.0	94	7.0
6.0	80	7.85
7.0	72	8.3
8.0	66	8.75
9.0	58	9.2
10.9	53	9.6
11.0	50	10.0

TABLE 1

Traditional solutions to this problem have often been based on a feedback loop which samples the direct output voltage and either controls the gain of a driving element in the generating chain or else modifies pulses feeding such an element, as in Figure 1. Figure 1 shows a typical high-voltage generator with a feedback loop controlling the gain of the transistor driving the primary of the step-up transformer which feeds the voltage multiplier.

I have found that by sensing the magnitude of the cyclical component in the external output circuit of a high-voltage generator and using the

information to vary the feed to the driving element of the generator in a novel way, the output current can be closely regulated over a much broader range of load resistance. The cyclical component consists of ripple impressed upon the direct output voltage in the course of its generation.

It will be appreciated that the output can be in the form of either positive ions or negative anions.

According to one aspect of the invention, we provide a step-up direct voltage generator circuit of the kind comprising a relatively low voltage alternating current source, and a voltage step-up and rectifying means arranged for transforming alternating current from the alternating current source into a relatively high voltage DC output, in which the generator circuit comprises an output stabilising means so arranged as substantially to stabilise the output of the generator circuit against changes in current, over a range of load impedances, the output stabilising means comprising a ripple sensing means arranged to sense voltage ripple in the generator circuit output, and feedback means for adjusting the input to the voltage step-up and rectifying means in response to the output of the ripple sensing means.

Preferably the voltage step-up and rectifying means comprises a step-up transformer feeding a Cockroft-Walton voltage multiplier.

The alternating current source conveniently comprises a pulse generator, and preferably an adjustable gating circuit is provided for adjusting the mark/space ratio of the output pulses of the pulse generator. The gating circuit is preferably adjusted in response to the feedback means thereby to adjust the input to the voltage and rectifying means.

When the generator circuit is arranged to provide a stabilised output current, the feedback means preferably comprises a voltage-controlled phase-shifting means.

According to a second aspect of the invention we provide an electronic microbicide apparatus comprising a step-up direct voltage generator circuit of the kind comprising a relatively low voltage alternating current source, and a voltage step-up and rectifying means arranged for transforming alternating current from the alternating current source into a relatively high voltage DC, in which the generator circuit comprises an output stabilising means so arranged as substantially to stabilise the output of the generator circuit against changes in current, over a range of load impedances, the output stabilising means comprising a ripple sensing means arranged to sense voltage ripple in the generator circuit output, and feedback means for adjusting the input to the voltage step-up and rectifying means in response to the output of the ripple sensing means.

Preferably the output of the generator circuit comprises an output electrode wherein in use the load impedance is proportional to the air gap distance between the output electrode and the target.

The output electrode preferably emits a stream of ions directed towards the target.

Preferably, the output electrode emits a stream of anions directed towards the target.

Two embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a block circuit diagram of a prior art high voltage generator in which an attempt was made to stabilise the voltage of the generator output utilising feedback based upon the DC voltage itself,

Figure 2 is a block circuit diagram of a first embodiment of the invention,

Figure 3 is a block circuit diagram of a second embodiment of the invention, and

Figure 4 is a more detailed circuit diagram of the second embodiment.

In the circuit of Figure 2 which utilises a multi-stage Cockroft-Walton voltage multiplier VM, the ripple component of the direct voltage developed across a ripple sensing element RSE in the external output circuit is shifted in phase to a degree controlled by its magnitude by feedback means FBM used to gate the output of the oscillator OSC using gating circuit GC. The result is modification of the signal triggering drive transistor Q, which in conjunction with resonances in the primary circuit of step-up transformer TRANS produces a voltage across the transformer secondary which varies in inverse proportion to the magnitude of the generator output voltage ripple. Since the amplitude of this ripple sample in general varies directly with the current flowing in the external output circuit, a negative feedback loop is achieved which is found to maintain the generator output current constant over a wide range of load resistance.

In the circuit of Figure 2 a fall in the output current will lead to a rise in the output voltage up to the full off-load output voltage capability of the generator. However, an additional requirement often encountered is to limit the maximum output voltage to a certain value, either for safety

reasons or to avoid insulation breakdown and flash-over in some part of the equipment. This additional requirement can be met by some such means as those illustrated in Figure 3 in which a limiter LIM is provided. The limiter should be configured to operate gradually enough to avoid the possibility of oscillation arising in the feedback circuit. One possible realisation of the arrangement of Figure 3 is illustrated in Figure 4.

The operation of the circuit shown in Figure 4 may be described as follows. The frequency of the oscillator OSC formed by logic gates a, b and their associated components is adjustable by the pre-set potentiometer SET f to achieve maximum power transfer in the step-up transformer TRANS. This adjustment is necessary because of resonances in the transformer primary circuit. A gating circuit GC formed by logic gates c, d and associated components modifies the signal from the oscillator OSC and triggers drive transistor Q, which switches a voltage across the primary of transformer TRANS. The voltage induced in the secondary of the transformer is rectified and multiplied by the five-stage voltage multiplier VM, the output of which consists of a direct voltage having a ripple of magnitude equal to that across the secondary of the transformer. This ripple is sampled by the potentiometer SET I, the amplitude of the sample increasing as the current through the potentiometer SET I increases.

The precise operation of the feedback circuit is not fully understood but the following is an explanation of how the feedback circuit is believed to stabilise the output.

The ripple sample is fed to operational amplifier P, whose output controls the action of the gating circuit GC. In combination with resonances in the transformer primary circuit this produces a voltage across the transformer

secondary which varies in inverse proportion to the magnitude of the output voltage ripple. Since this ripple varies directly with the current flowing in the external output circuit, feedback means FBM, (which may comprise a negative feedback loop), is achieved which is found to maintain the output current constant over a wide range of load resistance across the output of the generator. When the breakdown voltage of zener diode Z is exceeded operational amplifier L acts as a limiter, modifying the operating parameters of operational amplifier P to limit the maximum output voltage of the generator in a gradual and controlled fashion.

The feedback means may comprise a phase-shift network.

Tests conducted with one device using the circuitry of Figure 4 produced the results shown in Table 2, which contrast favourably with those shown in Table 1.

POINT/SURFACE DISTANCE (MM)	OUTPUT CURRENT (μA)
1.0	500
5.0	500
10.0	500
14.0	500
15.0	440
20.0	200
30.0	140
40.0	90

TABLE 2

CLAIMS

1. A step-up direct voltage generator circuit of the kind comprising a relatively low voltage alternating current source, and a voltage step-up and rectifying means arranged for transforming alternating current from the alternating current source into a relatively high voltage DC, in which the generator circuit comprises an output stabilising means so arranged as substantially to stabilise the output of the generator circuit against changes in current, over a range of load impedances, the output stabilising means comprising a ripple sensing means arranged to sense voltage ripple in the generator circuit output, and feedback means for adjusting the input to the voltage step-up and rectifying means in response to the output of the ripple sensing means.

2. A generator as claimed in claim 1, in which the voltage step-up and rectifying means comprises a step-up transformer feeding a Cockroft-Walton voltage multiplier.

3. A generator circuit as claimed in claim 1 or claim 2, in which the alternating current source comprises a pulse generator.

4. A generator circuit as claimed in claim 3 in which the mark/space ratio of the output pulses of the pulse generator is adjusted by an adjustable gating circuit.

5. A generator circuit as claimed in claim 4 in which the position of the output pulses of the pulse generator is adjusted by an adjustable gating circuit.

6. A generator circuit as claimed in claim 4 in which the phase of the output pulses of the pulse generator is adjusted by an adjustable gating circuit.

7. A generator circuit as claimed in any one of claims 4 to 6 in which the gating circuit is adjusted in response to the feedback means thereby to adjust the input to the voltage step-up and rectifying means.

8. A generator circuit as claimed in any one of the preceding claims which is arranged to provide a stabilised output current, and in which the feedback means comprises a voltage-controlled phase-shifting means.

9. A generator circuit as claimed in claim 7 in which the feedback means controls the gating circuit thereby adjusting the input to the voltage step-up and rectifying means and thereby providing a stabilised output current.

10. A generator as claimed in any one of the preceding claims comprising a limiting means associated with the feedback means and arranged to limit the range of adjustment performed by the feedback means.

11. A generator circuit as claimed in claim 10 as appended to claim 8 in which the limiting means is arranged to limit the amount of phase shift provided by the phase-shifting means.

12. A generator circuit as claimed in claim 10 in which the limiting means is arranged to limit the extent to which the feedback circuitry modifies the output pulses of the pulse generator.

13. An electronic microbicide apparatus comprising a step-up direct voltage generator circuit of the kind comprising a relatively low voltage alternating current source, and a voltage step-up and rectifying means arranged for transforming alternating current from the alternating current source into a relatively high voltage DC, in which the generator circuit comprises an output stabilising means so arranged as substantially to stabilise the output of the generator circuit against changes in current, over a range of load impedances, the output stabilising means comprising a ripple sensing means arranged to sense voltage ripple in the generator circuit output, and feedback means for adjusting the input to the voltage step-up and rectifying means in response to the output of the ripple sensing means.

14. An electronic microbicide apparatus as claimed in claim 13 in which the output of the generator circuit comprises an output electrode wherein in use the load impedance is proportional to the air gap distance between the output electrode and the target.

15. An electronic microbicide apparatus as claimed in claim 13 or claim 14 wherein the output electrode emits a stream of ions directed towards the target.

16. An electronic microbicide apparatus as claimed in claim 15 wherein the output electrode emits a stream of anions directed towards the target.

17. A generator circuit substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

18. A generator circuit substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

19. A generator circuit as claimed in claim 10 and substantially as hereinbefore described with reference to Figure 4 of the accompanying drawings.

The Patent Office

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Application No:	GB 9626023.7	**Examiner:**	David Summerhayes
Claims searched:	1-16	**Date of search:**	6 March 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G3U (UAE9)

Int Cl (Ed.6): H02M 3/28, 3/305, 3/315, 3/325, 3/335

Other: ONLINE: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2095439 A (SINGER)	1 at least
X	GB 2079014 A (ELECTROTECH)	1 at least
X	GB 1528985 (MAULE)	1 at least
X	GB 959620 (GEC)	1 at least
X	US 5420777 (MUTO)	1 at least
X	US 4706176 (KETTSCHAU)	1 at least
X	Patent Abstracts of Japan, No.187, Vol.07, No162, page 67 & JP58069462 A (Nippon Denki) 25.04.83	1 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.